Report of the Interagency

Optical Networking Testbed 3 Workshop

September 7 – 8, 2006
Tokyo, Japan

Jointly Sponsored by the

Department of Energy Office of Science
National Science Foundation
National Institute of Information and Communications Technology

Joint Engineering Team
of the Networking and Information Technology
R&D Program's
Large Scale Networking Coordination Group

Report of the Interagency (US) and
National Institute of Information and Communications Technology (Japan)
Optical Networking Testbed Workshop 3
September 7-8, 2006
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1. 0 Executive Summary

This is the summary report of the third annual Optical Networking Testbed Workshop (ONT3), which brought together leading members of the international advanced research community to address major challenges in creating next generation communication services and technologies. Networking research and development (R&D) communities throughout the world continue to discover new methods and technologies that are enabling breakthroughs in advanced communications. These discoveries are keystones for building the foundation of the future economy, which requires the sophisticated management of extremely large qualities of digital information through high performance communications. This innovation is made possible by basic research and experiments within laboratories and on specialized testbeds. Network research and development initiatives are driven by diverse motives, including attempts to solve existing complex problems, the desire to create powerful new technologies that do not exist using traditional methods, and the need to create tools to address specific challenges, including those mandated by large scale science or government agency mission agendas. Many new discoveries related to communications technologies transition to wide-spread deployment through standards organizations and commercialization. These transition paths allow for new communications capabilities that drive many sectors of the digital economy.

In the last few years, networking R&D has increasingly focused on advancing multiple new capabilities enabled by next generation optical networking. Both US Federal networking R&D and other national R&D initiatives, such as those organized by the National Institute of Information and Communications Technology (NICT) of Japan, are creating optical networking technologies that allow for new, powerful communication services. Among the most promising services are those based on new types of multi-service or hybrid networks, which use new optical networking technologies. Several years ago, when many of these optical networking research topics were first being investigated, they were the subject of controversial debate. The new techniques challenged many long-held concepts related to architecture and technology. However, today all major networking organizations are transitioning toward infrastructure that incorporates these new concepts. This progress has been assisted through the series of Optical Networking Testbed Workshops (ONT). Processes, such as these workshops, that allow for a common vision encourage widespread deployment of these types of resources among advanced networking communities. Also, such a shared vision enables key concepts and technologies to migrate from basic research testbeds to wider networking communities. The first (ONT1) outlined a general framework of key issues and topics and developed a set of recommendations (www.nren.nasa.gov/workshop7). The second (ONT2) developed a common vision of optical network technologies, services, infrastructure, and organizations (www.nren.nasa.gov/workshop8).

The ONT-3 workshop built on these earlier activities by expanding these discussions to include additional considerations of the international interoperability and of the wider impact of optical networking technology on networking in general. In accordance with this broader perspective, the workshop confirmed that future-oriented research and development is indispensable to fundamentally changing the current Internet architecture and to creating a global network that incorporates completely new concepts. The workshop also recognized that the first priority in allowing for this progress is support for basic research and development, including those based on international collaborative activities. Such cooperative activities are important for the global realization of interoperability of a new generation architecture.

ONT3 was co-sponsored by the Department of Energy (DOE), the National Science Foundation (NSF) and the National Institute of Information and Communications Technology (NICT), in cooperation with the Joint Engineering Team (JET) of the Large Scale Networking Coordinating Group (LSN CG) of the Networking and Information Technology Research and Development Subcommittee of the National Science and Technology Council (US) and the Ministry of Internal Affairs and Communications (MIC) of Japan. ONT3 was an invitation-only workshop that was held on September 7-8, 2006 and hosted by NICT in Tokyo, Japan. The workshop was scheduled to coincide with the Global Lambda Integrated Facility (GLIF) conference, which was held at the same venue the following week. Participants in ONT3 included representatives of advanced networking communities from around the world. The workshop was organized as a series of panel presentations by representative members of these communities. The workshop presentations and this report are available on the ONT3 web site. (http://www.nren.nasa.gov/workshop9.) The communities represented are indicated by panel titles: 1) The Future of Optical Networking and Communications: A 5-15 Year Perspective (Panel A), 2) Advanced Research Testbeds (Panel B), 3) Broad Range Technology Evaluation and Deployment Testbeds (Panel C), 4) Early Deployments of Innovative Advanced Optical Networking Services and Infrastructure and International Exchange Facilities (Panel D), and 5) Optical Networking Industry- Technologies and Systems (Panel E).

1.1 Vision and Themes

In advance of the ONT3 workshop, presenters and participants were encouraged to consider research topics not only in the narrow context of advanced optical networking but also in the wider context of issues related to networking in general, e.g., how advanced optical technology would - or could - create a substantially enhanced set of services and technologies for all networks. Also, presenters and participants were encouraged to consider the evolution of advanced optical networking in the context of implications for international networks, especially interoperability for services and technology at global exchange points. Several key themes that were discussed at the ONT3 Workshop are summarized in the following sections of this report. The themes are further expanded in subsequent sections.

1.2 A Vision of a Fundamentally New Network

Researchers have long recognized that to meet the changing requirements of the digital economy, a fundamentally new network must be created. The Internet comprises one of the most successful set of communications services technologies that has ever been developed.

Nonetheless, its very success and ubiquitous deployment globally has revealed basic limitations that must be removed if it is to continue to progress. To allow for continued success, further improvements must be made at many levels. In the past decade, there have been numerous publications on the range of current problems. Many of these publications have also noted that it is difficult to define a research and development process that could fundamentally change Internet architecture. The global installed Internet infrastructure is at once an extremely valuable resource and also a barrier to additional progress. The installed base of services and infrastructure impedes efforts to address required changes. Future developments have been hindered by the restrictions inherent in current implementations. However, within the last two years, a series of workshops and reports have recommended that a process be implemented that would be directed at “clean slate” approach. Instead of attempting to strive for marginal, incremental improvements, this approach would have as a goal achieving major, fundamental advancements. In part, this approach requires new theoretical and experimental research methods and new types of testbed facilities.

1.3 A Fundamentally New Approach to Network Research Testbeds

An important topic of discussion at ONT3 was the recognition of the need for not only for new theoretical and laboratory methods but also for new types of large scale testbeds to allow for major experiments. More than theory, lab simulation, and modeling are required for basic networking research. New types of large scale testbeds are required, especially those comprised of network resources that can be dynamically reconfigured. Such testbeds should also provide for gateways that can allow for selected access to multiple external communities. Recently, several new design concepts for such testbeds have been proposed, and some have been implemented, including those focused on optical networking research. To establish these new types of large scale testbeds, funding models including continuous governmental investment are also required.

1.4 Multi-Layer Networks

The Internet today is essentially a Layer-3 network, supported by a foundation of services at Layers 1 and 2. Recent network architectural designs have demonstrated the utility of multi-layer networks, which can complement L3 services with new types of L1 and L2 services. Such L1 and L2 services, especially when based on advanced optical networking techniques, can provide significantly more capacity and capabilities than networks that are limited to L3 services.

1.5 Optically Based Services

New optical networking services and technologies have been accepted as crucial components of next generation networks. Currently, new hybrid networking architecture that allows for complementing (supplementing) L3 services with L1 and L2 is being explored on research testbeds. However, also being investigated are new methods and techniques that provide options for completely by-pass L3 services with end-to-end L1 and L2 provisioning. These methods require a range of advanced optical network architectures and technologies that are being evaluated through testbed experiments. These developments are enabling new classes of optically based network services, including those that can be directly implemented on lightpaths.

1.6 International Interoperability

By necessity, all major communication services must be globally provisioned and operated. In order to provide for emerging next generation network services throughout the world, new architecture for global communication exchanges must be designed, developed, and implemented. Recent research and development projects have made significant progress in creating new, open, multilayer communication exchanges, in part, based on advanced optical networking technology. In the past several years, many of these activities have been conducted through the GLIF organization.

1.7 The Importance of Fiber as Fundamental Infrastructure

Recent advances in next generation communications services have underscored the importance of enabling network providers, government agencies, research organizations, and even individual application projects to have direct access to dedicated fiber resources. Furthermore, such entities must also be able to directly manage individual network resources, including individual lightpaths, using distributed processes. This requirement has been demonstrated by the purchase of thousands of miles of dark fiber by advanced networking organizations and by research and education organizations. These projects have already demonstrated dramatically lower costs for network deployments. In many cases, cost-effective solutions have been realized even when capitalized fiber builds were required.

1.8 Considerations for Individual Enterprises

To date, the majority of the next generation communication services and capabilities that have migrated from research testbeds to early implementations have been deployed on international, national, and regional networks, and at major communications exchanges. An important next step is to enable individual organizations to access such services. Currently, there have been few attempts to extend these new capabilities to sites within organizations beyond a minimal number of projects related to lab research. In order to continue progress toward advanced communication services, this challenge must be addressed.

2.0 Summary Workshop Report

This report summarizes the findings of the third annual Optical Networking Testbed Workshop (ONT3). This workshop brought together leading members of the international advanced research community to discuss major challenges in creating next generation communication services and technologies. Major themes for the workshop included new concepts of next generation optical networks, the potential impact of next generation optical networking technologies on networking in general, the importance of fundamental optical network research, especially on large scale testbeds, and the crucial need for international interoperability of services and technologies. The workshop presentations, list of participants, and this report are available on the ONT3 web site. (http://www.nren.nasa.gov/workshop9.) The ONT3 Workshop built on the success of two earlier workshops.

The first (ONT1) outlined a general framework of key issues and topics and developed a series of recommendations (www.nren.nasa.gov/workshop7). The second (ONT2) developed a common vision of optical network technologies, services, infrastructure, and organizations (www.nren.nasa.gov/workshop8). This common vision allows for widespread deployment of these types of resources among advanced networking communities. In particular, this type shared enables key concepts and technologies to migrate from basic research testbeds to wider networking communities. Participants at this workshop from many communities (research, advanced network organizations, government agencies, and industry) shared their roadmap frameworks for future research, development and implementation of advanced optical technologies. These roadmaps were presented to allow for comparative analysis and not to achieve a goal of creating a common roadmap. It was understood that the shared vision of the representative community did not necessitate a common roadmap, and that multiple roadmaps allowed for different approaches to be compared at early stages of development to assist in ensuring the deployment of only the best technologies.

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2.1 ONT3 Overview

During the last five years, networking research and development (R&D) communities have discovered major new methods and technologies that are enabling breakthroughs in advanced communications. These developments are continuing as researchers build on past successes and integrate networking components using novel architecture. These discoveries will provide the foundation capabilities for the future information economy. The new economy requires the sophisticated management of extremely large qualities of digital content using high performance global communications. Today's network research and development projects have been motivated by the need to resolve many types of problems.

For example, some research projects have been designed to address existing difficult problems related to scaling existing services, providing for increased capacity, optimizing resources, enhancing security, and enabling more effective management. Other projects have been motivated by a desire to create powerful new technologies to allow the creation of services and applications that cannot be supported by traditional networks. Many research projects have been established to create tools that are required to address specific challenges encountered by large scale science research or by government agency mission agendas. During the initial stages of R&D, it is usually difficult to determine which particular direction or technology will yield the greatest benefits. Consequently, it is essential to organize forums, such are the ONT workshops, that allow for information exchange among researchers who are investigating different aspects of similar basic problems.

Beyond discussions of basic research, the ONT forums address the need to share basic discoveries among research communities and to migrate them to wider communities. The transition of new discoveries to wider communities can occur through many processes. New discoveries can migrate by being transitioned to standards groups to allow for further discussion, formalization, and commercialization. They can migrate directly to commercialization without an intermediate standardization phase. They can be deployed through early implementation within research and education networks or within government agency networks.

During the last five years, much networking R&D has increasingly focused on advancing multiple new capabilities enabled by next generation optical networking. Initially, some of the topics addressed next generation optical networking research gave rise to debates over the degree to which these technologies should be developed to support end-to-end L1 and L2 services. However, today all major networking organizations are transitioning toward infrastructure that incorporates multilayer, rather than single layer, services and technologies.

Within the US, Federal networking R&D along with other national R&D initiatives have established several key projects that have advanced optical networking development and early implementation. In Japan, the National Institute of Information and Communications Technology (NICT) has designed and implemented a major testbed, JGN2, which includes multiple research projects focused on optical networking research. In several other Asia countries and in Europe, multiple advanced optical network testbeds have been established. During the last two years, several of these international testbeds have performed interoperability research experiments and currently plans are in formulation to continue this research on a larger scale.

2.2 Key ONT3 Themes and Concepts

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2.2.1 Key Research Issues

The majority of R&D activities that relate to advanced optical networking are taking place in laboratories and on customized experimental testbeds that have been designed specifically for this type of research. These projects are investigating methods, architectures, services, and technologies that will become the basis for the next generation of optical networks. The research community requires experimental optical network testbeds to validate lab results and to approximate real world scenarios. These testbeds enable researchers to solve challenging problems, usually based on technologies that may be difficult to design and develop initially. However, they have the potential to provide powerful new communication capabilities.

Some of the promising concepts and technologies that emerge from these activities migrate to early implementation by advanced networking organizations. These organizations undertake projects to evaluate optical networking services and technologies as part of their plans for future production offerings.

The following sections describe current optical networking research topics that were discussed at the ONT3 Workshop.

2.2.2 Application Drivers

Much optical networking research is driven by the need to solve generalized technology challenges. However, other research projects are motivated by the specific need to provide services for new applications. Given the scope of topics covered by this workshop, its format deliberately limited time devoted to discussions of application drivers. However, such drivers provided a major context for all the discussions, often more implied than explicit. Almost all optical networking testbeds provide resources to enable testing with real applications under conditions that are as close to real environments as possible. Testbed researchers attempt to communicate with application communities through on-going processes to ensure an understanding of their network service requirements. These dialogs also make advanced capabilities known in order that such communities can consider creating new applications. Such considerations include various new technologies such as methods for application signaling directly to optical networking resources to allow for dynamic provisioning.

Multiple ONT3 participants noted that, during the last three years, application showcases and demonstrations involving advanced optical networking capabilities have been organized. These events include iGRID 2005 (which was structured specifically to showcase applications that could benefit from advanced optical networking), the 2006 GLIF conference in Tokyo, and SC05 in Seattle and SC06 in Tampa.

2.2.3 Service Oriented Architecture (SOA) for Networks

The transition to Service Oriented Architectures (SOAs) is a macro trend across much of information technology. The optical networking research community is aware of the importance of leveraging the advantages of SOA of existing related development efforts to provide significant communication service enhancement and resource manageability. These efforts include utilizing the results of standardization efforts such as those developing the Web Services Resource Framework (WS-RF) and similar architecture. A related issue is the need to develop a network definition language (NDL) to provide for a common process-readable means to describe and interact with network elements.

2.2.4 New Network Architecture

Another macro trend is driven by the need to create a fundamentally new network architecture, an objective that provides for a larger context than those that are only focused specifically on optical networking. There are several aspects to the current efforts to create new network architecture.

One key objective is the creation of a true multi-layered, multi-service network. Currently, the Internet is primarily a Layer-3 network, an overlay network supported by Layer 1 and 2 services. New network architectural designs allow for complementing L3 services with L1 and L2 services (and in some cases L2.5), including by the complete elimination of L3 paths among sites served. This new architectural design can provide with significantly more capacity and capabilities than networks that are limited by exclusive dependencies on L3 services. These initiatives require the design of new control planes, management planes, and service planes.

Another objective is to create an architecture that will allow for substantially more interoperability among multiple network domains. Such interoperability includes services integration across domains as well as resource provisioning. In addition, the new architectural model provides for more direct access to core network resources, for both utilization and reconfiguration, from communities of network service users. Also, several major research initiatives are being planed to explore the potential for improving the Internet by revising its fundamental architecture.

2.2.5 Common Services Architecture

To provide for inter-domain service provisioning, a common service architecture is required, including precise formalized service definitions that are publicly documented, widely known, and well understood. Through various cooperative processes, the optical networking research testbed community has been developing concepts, especially for optical transport, that could lead to such an architecture. Prototypes have been implemented and demonstrated on national and international testbeds.

2.2.6 Common Services Provisioning

The optical testbed research community is exploring various options that will allow for end-to-end inter-domain services provisioning at Layer 1 and Layer2. After a Common Services Architecture is designed and developed, it is necessary to develop policies, procedures, and processes for Common Services Provisioning across multiple domains. Developing these capabilities requires the potential to advertise network resources across domains and to provide for interdomain signaling and resource allocation, using secure and manageable processes. Such provisioning must have the option of being dynamic or static. During the last five years, much research has focused on interdomain lightpath provisioning. These activities rely on new architecture for data planes, management plans, control planes, and service planes. Inter-domain dynamic lightpath provisioning has been demonstrated at a number of national and international advanced networking forums.

2.2.7 Global Open Exchange Point Architecture

The optical network testbed research community has made significant progress in defining an architecture for next generation communications multi-domain exchange points. Traditional exchange points provide for peering at L3 only. New exchange points provide for traffic exchange at multiple layers across domains, including L1. Such facilities are those that can provide support for Common Services Provisioning. Issues related to these exchanges include developing frameworks for well understood layer technical definitions, defined common services, provisioning processes, management, control, operations, monitoring, measurements, security and fault detection and response. Currently, these efforts are being led by the international GLIF organization.

The international networking researcher community has initiated several cooperative projects under auspices of the GLIF organization to design open exchange point architecture, services, and facilities. The ONT2 report noted that it was "premature" to attempt to provide for widespread global multidomain interoperability. However, during the last year, much progress has been made toward this goal. Data plane interoperability among multiple domains has been demonstrated on an international testbed for over five years. Also, this capability has been developed and implemented as a prototype between several communications facilities through work on global interoperability within the GLIF community. During the GLIF conference following the ONT3, a demonstration took place of international multi-domain lightpath provisioning using novel control and management planes. The optical networking research community is continuing to work with the GLIF community to define and implement global lightpath service architecture and facilities.

2.2.8 Global Open Exchange Points

The ONT2 Workshop report noted that by September 2006 the research community "should have several operational optical Open Exchange Points (OEPs) with services based on agreed common service definitions." That report recommended that "ONT providers should work with the existing GLIF activities that have been established to implement global interoperability."

The report also recommended that progress toward that goal be reviewed at ONT3. Primarily, under guidance from GLIF initiatives, the following Open Exchange Points (OEPs) have already been implemented at Layer 1. In September 2005, iGRID presented a showcase of multiple applications that required the use of advanced optical networks. Many of these applications used established GOLEs. Several other events, including SC05 and SC06 used Open Exchange Points (OEPs) to support interoperable bandwidth requests, interdomain management, and other service requests**.** These facilities have been termed "Global Open Lambda Exchanges (GOLEs).

Using the emerging GLIF architecture, they have been labeled Global Open Lambda Exchanges (GOLEs). In addition, the NGIX-East in the Washington DC area, which currently switches inter-testbed traffic at Layer 1, may soon provide Layer 1 OEP services.

- AMPATH (Miami)
- CANARIE – StarLight (Chicago)
- CANARIE-PNWGP (Seattle)
- CENIC LA PoP (Los Angeles)
- CERN (Geneva)
- CzechLight (Prague)
- KRLight (Seoul)
- MAN LAN (New York)
- NetherLight (Amsterdam)
- NorthernLight (Stockholm)
- Pacific Northwest GigaPoP (Seattle)
- StarLight (Chicago)
- T-Lex (Tokyo Lambda Exchange) (Tokyo)
- UKLight (London)

2.2.9 Architecture and Services Standardization

The ONT research community has been communicating its new architectural concepts, particularly those related to interoperability, to wider communities. For example, internationally, the GLIF is coordinating the implementation of emerging new architectures at interdomian services and facilities, including new types of distributed management and control planes. Many basic research issues remain, including creating common definitions, interdomain and application policy-based access methods, and instantiation methods at multiple levels (e.g., network, operations, business), interoperability methods, and measurement techniques (e.g., for security, data integrity, performance, and validation). Optical networking researchers are currently planning a new generation of large scale optical research testbeds by defining their objectives, processes, operations, and support models. The research community is also participating in the activities of standards organizations, including the IETF, ITU, and the IEEE. Also, other initiatives are being coordinated globally through the GLIF, which is developing and implementing methods for intra- and inter-domain dynamic provisioning and routing. The GLIF has also established a common communications initiative with the Open Grid Forum (OGF, a standards organization that was, until recently, termed the Global Grid Forum - GGF), through its High Performance Networking Research Group.

2.2.10 Optical Network Operations and Management

New optical networking architecture, services and technologies require operational and management capabilities that are substantially different from traditional networks, especially from traditional networks that are only oriented to L3 services. The majority of management and operational tools today are oriented toward L3 networks services. Many required tools for emerging network services, especially for multi-layer, multi-service networks, do not exist or are available only in preliminary forms. Also, the commonly used metrics for analysis used on L3 networks often do not provide for meaningful insight into traffic patterns on L1 and L2 networks.

Two particularly important components for next generation optical networks are specialized management and control planes. An extensive range of integrated functionality is required, including those for monitoring traffic performance, paths, and resource utilization and allocation, recording, modeling, analyzing, and optimizing traffic patterns, providing capacity, detecting and responding to problems, enabling fault isolation, ensuring security, and simulating future conditions to plan for changes and enhancements.

2.2.11 Optical Network Research Testbed Cost Models and Funding

Although basic research in optical networking has been recognized as a crucially important activity that provides major benefits to the general economy, this research has not received appropriate funding. In part, this circumstance results from the misperception that the communications industry has established major initiatives in this area. However, the communications industry is primary oriented to near term goals and to incremental improvements of existing technologies, whereas basic research is oriented to long term objectives and to the creation of fundamentally new technology.

Beyond the level of funding, another persistent problem has been the inconsistency of funding. The level of funding available from year to year, especially for many individual topic areas fluctuates highly without consistency. Long term basic network research funding should be consistent to attract researchers - including students, especially graduate students working on advanced degrees. Usually such students must commit to exploring a topic over the course of several years, especially when pursuing an advanced degree. Often over the span of a few years, changes in research policy sometimes results in major shifts in research funding levels and allocations for specific research topics. Research funding adjustments are essential to enable new areas to be explored and to prevent subsidies to mature or unproductive areas. However, such changes must be determined within a larger context of consistent policy objectives.

Also, when developing funding models for network research, it is important to recognize the need for large scale optical testbeds. Cost models for research testbeds should be designed to successfully achieve the goals of the research community. It is possible to develop cost effective models for such testbeds. For example, an essential resource for optical network testbeds is dark fiber, which can substantially lower long term operations costs. Another method for lowering cost is to ensure that open standards for architecture and open source software is utilized. Longer term research goals can be compromised when insufficient resources forces dependency on external organizations with short term objectives. Basic research is most successful when not directed by short term goals. To accomplish these network research goals, persistent funding over time is needed for basic research and for regularly refreshing the optical testbed technology. Participants also recommended research funding for interdisciplinary projects, which may require policy changes at some agencies that primarily support existing disciplinary areas. In addition, participants recommended funding specifically for innovative research projects among testbeds.

2.3 Conclusions

Multiple drivers are motivating advanced network research, including the need for new applications and services, the growth in usage of existing applications and services, requirements for resource efficiency, for security, and for cost effective management and operations, and innovation in basic architecture and technology. These drivers give rise to major challenges that could become barriers to designing and developing next generation communications. Currently, research is being conducted on multiple optical research testbeds world-wide that is directly addressing these challenges. Although many new optical networking techniques and technologies are discussed in the context of addressing requirements for extremely high volumes of data traffic, recent research has demonstrated that optical networking provides solutions to a wide range of requirements beyond those related to stream volume.

Already new innovations are beginning to resolve many other complex problems that previously have been considered intractable. These innovations will influence networking at all levels – not only at the optical layer. The majority of advanced networks today are beginning to design services based on new types of multi-service or hybrid networks, using emerging optical networking technologies as a foundation. Many workshop participants noted that several years ago, when many of these optical networking research topics were first discussed, they became controversial topics -- because they challenged traditional concepts of networking services, architecture, and technology. However, today all major networking organizations are transitioning toward infrastructure that incorporates these new methods. A key observation noted at this workshop was the importance of establishing international communications exchange points that allow for interoperability of services at all levels - made possible through architecture based on widely recognized standards.

Workshop participants also noted that new research initiatives in optical networking must be established to continue this progress, especially research based on large scale optical testbeds. In previous years, the majority of traditional networking organizations expected new communications technology to have a productive life cycle of many years, even decades. It must now be recognized that the era of dependence on long life cycles for communications technology is over. Innovation for communications technology must be continuous at all levels, and, especially given the recent success of research conducted on optical network testbeds, particular focus should be directed to programs that support basic optical and photonic research using large scale infrastructure. In general, to allow for major advances, not simply incremental improvements, optical research must be provided with adequate funding to complete multi-year agendas and to address long term needs, not only short term requirements.

2.4 Summary

As the global economy becomes increasingly dependent on digital information, sophisticated communications architecture, technology and infrastructure must be continually designed, developed and implemented in an ongoing process of innovation and deployment. A key to a viable future economy will be digital communications based on a foundation of next generation optical networks, which will be part of a distributed, world-wide facility. Innovations in advanced optical networking will be crucial to resolving fundamental challenges in high performance, agile communications for the foreseeable future. Continued investments in such research, especially conducted through experimentation on large scale testbeds is critical not only for the communications industry but for all segments of the 21st century economy.

Appendix A: ONT3 Workshop Structure and Topics

To assist in setting the themes for the workshop, Hiromu Momma, of Japan's MIC gave a presentation on "Trends in ICT Policy in Japan," which provided an overview of major trends for all major communications research and development themes in Japan**.** Tomonori Aoyama, from NICT and Keio University, gave a keynote presentation on "New Generation Networks (named NWGN)," which were contrasted with efforts to create a "Next Generation Network (named NXGN)." The NXGN initiative was designed and is being standardized by the ITU-T to improve the existing IP network, e.g., to provide triple play services and quadruple play services with FMC (Fixed Mobile Convergence). NXGN is now in the development phase and services over NXGN will start soon. In contrast, the NWGN initiative will fundamentally change the basic architecture and technologies of IP networks, and it may take more than ten years to realize this goal. Because the primary focus of the ONT3 workshop was optical networking services and technologies, the topic of specific next generation applications enabled by NXGN was a minor theme. However, the topic of enabling applications over NWGN was an important contextual topic for the Workshop. Consequently, the second day keynote, presented by Tom DeFanti (University of Illinois, UCSD), provided a vision of future digital media applications with a description of the CineGrid™ initiative.

A.1 The Future of Optical Networking and Communications: A 5-15 Year Perspective (Panel A)

Fumito Kubota (NICT) introduced Panel A by providing an overview of the basic panel themes.

Guru Parulkar (NSF) presented "GENI Backbone Node Hardware Architecture." The NSF GENI project (Global Environments for Networking Innovations) (www.nsf.gov/cise/geni) is a major US National Science Foundation initiative that has been designed to provide a distributed experimental facility that will be provide major testbed capabilities for a new generation of researchers. The GENI initiative envisions a research program and a global experimental facility designed to explore new network architectures at a very large scale. The initiative will design and implement a facility capable of exploring creating new core network functionality, deploying and validating new network architectures, building higher-level service abstractions, and building new services and applications. GENI is envisioned as a broad community effort that will engage other US federal agencies as well as research communities in other countries, and within corporate organizations.

Masaki Hirabaru (NICT) presented the Akari Project, an "Initiative on Designing a New Generation Network," undertaken by the NICT Network Architecture Group. The goal of this project is to fundamentally change the basic architecture and technology of future networks, in part, by closely integrating optical paths and optical packets and providing transparency by avoiding Optical-Electrical-Optical (OEO) conversion. This research project will lead to a future all optical network that would be the foundation of other network services, including edge services such as wireless.

Peter Kaufmann (DFN) provided “Some Future Perspectives” from a European point of view, which included an overview of the need to address challenges related to large scale future capacity requirements, hybrid networks, intelligent optical VPNs, signaling, inter-domain operability, virtualization at all levels, operations, security, cost models, and governance policy.

A.2 Advanced Research Testbeds (Panel B)

The focus of Panal B was the direction of current activities and research taking place on advanced research testbeds, specifically those focused on specific fundamental research topics. Panel participants described how optical networking will change the way networks are used. For example, new control technology permits an application, in principle, to set up one or more end-to-end “lightpaths,” which could provide it with hundreds of Gbps of aggregate bandwidth that would be fully dedicated to the application. Using lightpaths, applications may directly allocate their own network resources much like they allocate physical memory in computers. This capability completely removes bandwidth bottlenecks that many data-intensive applications encounter in today’s networks. Also, new capabilities allow the applications to configure and reconfigure their own network topology, which could consist of true end-to-end lightwave connections - without intermediate queuing, manual NOC intervention, or cross-interference from other processes.

OptIPuter

Tom DeFanti, University of Illinois, UCSD and UIC, presented the OptIPuter, a project funded by the US National Science Foundation that is exploring the implications of a new paradigm for future distributed information technology that is designed specifically to take advantage of high performance optical networks. These techniques become especially important as the network outside the computer becomes much faster than the connections inside.

G-lambda

Tomohiro Kudoh, AIST, presented the G-lambda project, which is creating new architecture and network service interfaces that are allowing for national and international Grid infrastructure to be integrated and operate as a single set of common, scheduled resources. In the week following the Workshop, this research group demonstrated this capability in partnership with the US Enlightened research project, using a multi-domain international testbed provisioned between Japan and USA. The particularly techniques used comprised the world’s first demonstration of these capabilities on a multi-domain integrated international testbed.

EnLightened

Yufeng Xin, MCNC, presented the Enlightened testbed, a US national infrastructure which is being used to develop new techniques and technologies for optical control planes. This testbed has been extended to enabling integration with international testbeds, including JGN2. The Enlightened research group demonstrated this capability as a joint project with G-Lambda during week following the ONT3 Workshop.

Lambda User Controlled Infrastructure for European Research (Phosphorous)

Cees DeLaat, University of Amsterdam, described a recently announced testbed funded by the European Union. Recently, re-named Phosphorous, this testbed is researching new optical networking architecture and technologies. This testbed will be used for multiple research and experiments, including those related to multi-domain interoperability

JGN2

Asako Toyoda, NICT, explained the concepts behind the design and implementation of JGN2, a national testbed that provides nationwide experimental Ethernet, IP network and optical network testbeds that support research and development. JGN2 also has implemented international testbed networks linking Japan with USA and Asian countries to promote research and development in collaboration among domestic and international research institutions. More than 120 research projects have been conducted utilizing the JGN2 network. JGN2 has supported many advanced networking technologies including photonics network technologies such as the first transmission using WDM 1,000 wavelengths, quantum cryptography, and many application experiments such as IPv6 multicasting, e-learning, etc.

StarPlane

Cees DeLaat, University of Amsterdam, described the StarPlane research testbed. A goal of this research is to design and develop a photonic network infrastructure that can be manipulated by Grid applications to optimize the performance of specific e-Science applications. StarPlane will use the physical infrastructure provided by SURFnet6 and the distributed supercomputer DAS-3. Hybrid optical networks such as SURFnet6 allow network administrators to partition the network and to create multiple overlay networks, each with a different logical topology. The novelty of StarPlane is that it provides this flexibility directly to the applications by allowing them to choose the logical topology in real time, ultimately with extremely fast switching times.

DRAGON

Tom Lehman, ISI and Jerry Sobieski, MAX, presented The DRAGON architecture utilizes Generalized MultiProtocol Label Switching (GMPLS) as its basic building block for network element control and provisioning. The key functional elements in the DRAGON control plane architecture are a) Network Aware Resource Broker (NARB) b) Virtual Label Switch Router (VLSR) and c) Client System Agent (CSA). DRAGON is working with the GLIF community in demonstrating the extensibility of the techniques being developed by that testbed. The DRAGON research project is working with the GIG-EF researchers on interoperable networking for Haystack Observatory facilities

OMNInet

Joe Mambretti, Northwestern University, presented the OMNInet testbed, which is being used developing new services, architecture, and technologies for next generation optical networks, including new methods for multiple domain optical interoperability, for example, with new control plane architecture. OMNInet research activities include those related to specialized protocols, signaling, lightpath provisioning, extensions to standard control architectures, such as IETF GMPLS, optical network subsystems and components, wavelength switching, cross-layer network intelligence, network interfaces, optical transport, optical network intelligence, and wavelength routing. OMNInet has also been directly integrated with multiple Grid applications and services.

VIOLA

Peter Kaufmann, DFN, described the VIOLA testbed in Germany, which is being used as an integrated testbed for applications and advanced network services. The testbed activities were organized under a consortium structure with partners from industry, research laboratories, universities and the DFN association. The testbed is investigating a wide range of services and technologies related to communication services.

KREONet2

Minsun Lee, KISTI, noted that Korea has invested tens of billion dollars in building its national network infrastructure. For more than a decade, Korea has made major investments in optical infrastructure resulting in a dense national coverage by its National Network, which now spans the complete peninsula. Korea now has the world's best national public network for broadband service to the home, having 8.6 M homes connected (60%). Internet users comprise 51% of the population. Korea continues to innovate, including by utilizing major optical testbeds, to ensure that this progress continues.

A.3 Broad Range Technology Evaluation and Deployment Testbeds (Panel C)

Panal C described testbeds that have been designed for broad range technology evaluation and early technology deployment.

UltraScience Net (USN)

Nagi Rao, DOE, explained that the US Department of Energy established the UltraScience Net (USN) to develop and inter-coordinate interoperability, services, and security among its major facilities. Key drivers have been next generation applications including those related to remote control of high-speed optical confocal microscopes (which generates high-resolution imagery with requirements for low latency and low jitter), high energy physics applications, astrophysics, and new file systems, such as LUSTR. Investigative topics include pre-GMPLS network design, implementation and operational experience, resource reservation, multiple path scheduling algorithms, and L2 measurement and analysis. USN has initiated inter-operability projects with other testbeds and plans to expand these activities to others, such active or proposed testbeds include CHEETAH, DRAGON, GIG-EF and HOPI.

WIDE

Hiroshi Esaki, The University of Tokyo (WIDE/NICT), described the WIDE project, which is focusing on new distributed computing architecture, which assumes very high speed communication infrastructure. Measures of actual commercial traffic pattern among Japanese commercial ISPs have shown that traffic is now symmetric, rather than asymmetric as in the past, e.g., primarily oriented to downloading oriented traffic. This change in traffic patterns requires changes in basic network architecture. WIDE is developing guidelines and semantics for testing L1-L3 technologies.

SINET

Jun Matsukata, NII, presented plans for a new SINET, which has been designed and is close to being procured. SINET3 will be launched in the spring of 2007. SINET3 will support hybrid services including legacy shared IP service and dedicated end-to-end channel. A variety of end-to-end services are provided using technologies of different layers (L1, L2, and L3). Management functionality for this network is a future research topic.

National Lambda Rail

David Reese, NLR, described The National Lambda Rail (NLR), which is a national fiber infrastructure facility that is capable of providing multiple wavelengths for the research community – one half of its capacity has been allocated for research and development projects. NLR is defined as not a single network but a set of facilities, capabilities and services to build both experimental and production networks at various layers, allowing members to acquire dedicated (project specific) facilities or shared (community specific) facilities as appropriate. The NLR provides services and connectivity at L1 through L3. NLR provides the Research Waves, a virtual research network that provides wide variety of networking technologies for many different research projects. The NLR is addressing optical switching, operational requirements and related technologies.

HOPI, NewNet

Rick Summerhill, Internet2, introduced "NewNet," the new Internet2 Network and HOPI. The new Internet2 Network will provide L1 and L2 services as a replacement for Abilene, which will be terminated in October 2007. HOPI is a national testbed that provides a hybrid service of shared IP packet routing with some switching capability for dynamically provisioned circuits, i.e., hybrid optical and packet switching, using MPLS tunneling. The control plane used is the one developed by the DRAGON project. HOPI is developing operations that serve all layers of the protocol stack, working on interdomain interoperability across optical networks, and providing support for new applications. HOPI is also working with regional networks and international networks.

A.4 Early Deployments of Innovative Advanced Optical Networking Services and Infrastructure and International Exchange Facilities (Panel D)

Panal D described early deployments of innovative advanced optical networking services and infrastructure, including those being supported by international exchange facilities.

Global Lambda Integrated Facility (GLIF)

Kees Neggers, SURFnet GLIF described the Global Lambda Integrated Facility (GLIF) (www.glif.is), an international virtual organization that promotes lambda networking (e.g., wavelength-based services) to support data-intensive scientific research and middleware development. GLIF has brought together senior networking engineers and researchers to design and develop an integrated international lambda infrastructure by identifying equipment, connection requirements, and needed engineering functions and services. These capabilities are currently being offered through a global distributed infrastructure based on advanced optical networking. The GLIF participants are national research and education networks (NRENs), consortia, and institutions working with lightpaths on optical networks. One objective is create agreements on global approaches to control plane interoperability – to ensure that there is a global approach to control plane interoperability, instead of a proliferation of national or regional approaches.

GMPLS/JGN2

Tomohiro Otani, NICT/KDDI Lab, provided a description of the GMPLS and optical cross connection testbed of JGN2. This project is developing multi-layer management technology including capabilities for wavelength provisioning and control, enhancements of GMPLS reliability and performance, and Exterior Network-to-Network Interface (E-NNI) management capabilities. The project has been extended to include enhancement of capabilities for GMPLS tunnels.

TransLight/StarLight

Maxine Brown, University of Illinois, noted that the StarLight community is working with the global advanced networking community to allow next generation connectivity for US and international research networking at all layers. StarLight has implemented prototype L1/L2 based services, as a complement to its L3 services. StarLight has made these services available to the national and international research community as well as to global science communities. StarLight has implemented a fully operational GLIF Open Lambda (Lightpath) Exchange. StarLight provides on-going support for advanced applications and testbeds using these services.

SURFnet6, NetherLight

Kees Neggers, SURFnet, explained the design and development of SURFnet, which is focused on global end-to-end interoperability**,** access to dark fiber for the backbone and for the customer, interdomain interoperability, protocols, user support, and implementing exchange points, including those using advanced optical technologies, such as NetherLight. SURFnet is collaborating within the GLIF to implement data plane, Layer 1 interoperability. SURFnet6 has implemented a fully operational GLIF Open Lightpath Exchange. Interoperability has been implemented among Netherlands (NetherLight), Chicago (StarLight), Seattle (Pacific Wave), and New York (Manhattan Landing - MAN LAN).

UKLight

Peter Clarke, University of Edinburgh, noted that UKLight was developed to support large scale science projects in the UK, and it has been used successfully for multiple experimental research projects. SuperJanet5 and UKLight combine to provide UK-wide hybrid network services. Currently, the national lightpath service from UKLight is being transferred to SuperJanet5. Future research involves a wide range of topics, including those related to Grid computing.

AARnet3

Mark Prior, AARnet addressed requirements for next generation optical networking in Australia, which provide support for AARnet. AARnet is currently deploying a new dark fiber facility to support key hybrid network in the South-Eastern part of Australia. Also described were the challenges of designing financial and business models for such networks.

T-Lex

Akira Kato, The University of Tokyo (WIDE/NICT), listed the research and implementation activities related to T-Lex, a GLIF open exchange in Tokyo. Key topics included service test, trials and demonstrations, such as Internet2 Land Speed Records for IPv4 and for IPv6, which are supported by T-LEX and related facilities.

*CA*net4*

René Hatem, CANARIE, provided a historical overview of CA*net 4 and presented its future directions, including the development of new techniques for providing users with more control to manage, deploy, and use optical networking resources, such as through implementation of Service-Oriented-Architecture (SOA) techniques and sophisticated high level work flow processes. CANARIE has pioneered the development and implementation of many new techniques for segmenting optical networks and for providing users with direct control over those segments.

Optical Testbeds in China

Tang Haina, Chinese Academy of Sciences (CAS), indicated that one of the key resources for the testbed activities in China is the HKLight GLIF open communications exchange in Hong Kong. This exchange provides a major connection to the Global GLORIAD network, a joint partnership among China, USA, Russia, Korea, Canada, the Netherlands, and the Scandinavian countries. In 2007, GLORIAD (Global Ring Network for Advanced Applications Development) will be a global 10 Gbps ring that circumnavigates the world. In China, GLORIAD is connected to CSTNET.

Ampath/WHREN

Heidi Alvarez, Ampath, presented the Western Hemisphere Research and Education Network (WHREN) and a related project – Links Interconnecting Latin America (LILA), which are being funded by the National Science Foundation. Ampath is a GLIF open exchange point in Miami that interconnects with the AtlanticWave along the east coast and provides support for circuits to South America. These projects have formed cooperative networking projects with multiple partners in Latin America to enhance international networking services and technologies in that region.

NREN

Kevin Jones, NASA, described NREN Wide Area Network (WAN), a nationwide high-performance network platform for the deployment of emerging networking technologies and for prototyping of applications and collaborative processes that will be enabled by these technologies. The NREN WAN provides connectivity between selected NASA centers and peers with other high-performance network testbeds to enable NASA scientists, engineers, and researchers to reach their partners within other Federal agencies and academia.

Global Information Grid – Experimental Facility (GIG-EF)

Lou Berger, LabNet/NRL, explained the GIG-EF strategy, which includes considerations of large scale distributed applications, high performance data transport, signaling using SIP, distributed file systems, including extensions to the desktop, Web services, native IPv6, and end-to-end QoS/QoP for data-intensive streams. The GIG-EF is collaborating on research with the Mid-Atlantic Exchange (MAX) ATDnet (using the same fibers), DRAGON, and BOSSnet to provide connectivity to the Haystack Observatory. These communities currently switch wavelengths among these networks (using optical switching implemented with GMPLS) and with the Naval Research Laboratory (NRL) at the physical layer data plane and the control plane layer.

A.5 Optical Networking Industry - Technologies and Systems (Panel E)

The Panal E participants presented key optical and photonic networking industry research and development in architecture, technologies, systems, subsystems and components. These topics included considerations of transparency, 100 terabits per second routers, high performance optical switches, tunable lasers, non-regenerative repeaters, enhanced FECs, adaptive, optical/electronic equalizers, wavelength converters, photonic integrated circuits, all optical 3R regenerators, nano-speed optical switches using chip formats, optical burst switching, and WDM using 1000+ lambdas, and others. The Panel E primary topics and speakers are listed here.

100 Tera Router
Ken-ichi Sato, Nagoya University

Integrated Optical Systems
Rod Wilson, Nortel Research Labs

160 Gbps-Based Field Transmission
Tetsuya Miyazaki, NICT

Optical Switches
Keiichi Nashimoto, Nozomi Photonics

UCLPv2
Sergi Figuurola, I2cat

Optical Packet Switches
Hiroaki Harai, NICT

Optical Burst Swtiches
Tsuyoshi Yamamoto, Fujitsu

1000WDM
Toshio Morioka, NICT

Appendix B: Workshop Administration and Attendees

Workshop Organization and Administration

Workshop Co-Chairs

Tomonori Aoyama, Keio University / National Institute of Information and Communications Technology (NICT)
Joe Mambretti, International Center for Advanced Internet Research (iCAIR), Northwestern University

Logistic Coordinators

Scott Macdonald, e-Side
Sally Miller, NASA

Organizers and Participants

Akira Amemiya, National Institute of Information and Communications Technology (NICT)
Hiroaki Harai, National Institute of Information and Communications Technology (NICT)
Koichi Hiragami, National Institute of Information and Communications Technology (NICT)
Masaki Hirabaru National Institute of Information and Communications Technology (NICT)
Kunihiro Kato, National Institute of Information and Communications Technology (NICT)
Yusuke Komatsuzaki, National Institute of Information and Communications Technology (NICT)
Grant Miller, National Coordination Office
Makoto Nagao, National Institute of Information and Communications Technology (NICT)
Asako Toyoda, National Institute of Information and Communications Technology (NICT)
Takayuki Nakao, National Institute of Information and Communications Technology (NICT)
Guru Parulkar, National Science Foundation (NSF)
George Seweryniak, Department of Energy (DOE)
Kazuhiko Yamamoto, National Institute of Information Communications Technology (NICT)

Other Participants

Shigeyuki Akiba, KDDI R&D Laboratories
Heidi Alvarez, FIU
Isao Arai, KDDI Corp.
Soichiro Araki, NEC Corp.
Tohru Asami, The University of Tokyo
Yoshifumi Atarashi, Alaxala Networks, Corp.
Lou Berger, LabN Consulting L.L.C, NRL
Maxine Brown, University of Illinois at Chicago

Ok-Hwan Byeon, KISTI
Juan Castilleja, CUDI
Peter Clarke, National e-Science Centre
Steve Cotter, Internet2
Matt Crawford, Fermilab
Cees De Laat, University van Amsterdam
Thomas DeFanti, UIC / UCSD
Hiroshi Esaki, The University of Tokyo
Sergi Figuerola, Fundacio i2CAT
David Foster, CERN
Kensuke Fukuda, National Institute of Informatics (NII)
Roberto Garcia, UANL
Chin Guok, DoE / ESnet
Kazuo Hagimoto, Nippon Telegraph and Telephone Corporation (NTT)
Tang Haina, Computer Network Information Center Chinese Academy of Sciences
René Hatem, CANARIE
Laurin Herr, Pacific Interface
Tetsuhiko Hirata, HITACHI. Ltd.
Haruhisa Ichikawa, Nippon Telegraph and Telephone Corporation (NTT)
Yoshikazu Ikeda, Tokyo Institute of Technology
Ichiro Inoue, Nippon Telegraph and Telephone Corporation (NTT)
Masugi Inoue, National Institute of Information and Communications Technology (NICT)
Osamu Ishida, Nippon Telegraph and Telephone Corporation (NTT)
Hiroki Ishihara, Ministry of Internal Affairs and Communications (MIC)
JJ Jamison, Cisco Systems
Masahiko Jinno, Nippon Telegraph and Telephone Corporation (NTT)
Ronald Johnson, University of Washington / Pacific Wave
Kevin Jones, NASA / NREN / NASA Ames Research Center
Dan Jordt, University of Washington Pacific NorthWest GigaPop
Toshiyuki Kanou, NEC Corp.
Yukio Karita, High Energy Accelerator Research Organization (KEK)
Akira Kato, The University of Tokyo / WIDE Project
Peter Kaufmann, DFN
Tatsuzo Koga, Tsukuba Research Center, NICT
Kazunori Konishi, APAN / KDDI Labs.
Katsushi Kouyama, National Institute of Information and Communications Technology (NICT)
Fumito Kubota, National Institute of Information and Communications Technology (NICT)
Tomohiro Kudoh, National Institute of Advanced Industrial Science and Technology (AIST)
Seung Jai Kwak, KISTI
Joseph Lappa, Pittsburgh Supercomputing Center
Minsun Lee, KISTI
Thomas Lehman, USC / ISI
Mathieu Lemay, Inocybe Technologies Inc.

Te-Lung Liu, National Center for High-Performance Computing
Jun Matsukata, National Institute of Informatics (NII)
Yuichi Matsushima, National Institute of Information and Communications Technology (NICT)
George McLaughlin, PNWGP / ANU
Tetsuya Miyazaki, National Institute of Information and Communications Technology (NICT)
Takashi Mizuochi, MITSUBISHI Electric Corp.
Hiromu Momma, Ministry of Internal Affairs and Communications (MIC)
John Moore, MCNC
Hiroyuki Morikawa, The University of Tokyo
Toshio Morioka, National Institute of Information and Communications Technology (NICT)
Kuniaki Motoshima, MITSUBISHI Electric Corp.
Akihiro Nakao, The University of Tokyo
Kiyohide Nakauchi, National Institute of Information and Communications Technology (NICT)
Gaku Nakazato, Ministry of Internal Affairs and Communications (MIC)
Keiichi Nashimoto, Nozomi Photonics Co., Ltd.
Kees Neggers, SURFnet
Wai Ng, US DoD
Koichi Ohashi, Ministry of Agriculture, Forestry and Fisheries Network (MAFFIN)
Yukifusa Okano, Tsukuba JGN2 Research Center, NICT
Katsuya Okubo, Ministry of Agriculture, Forestry and Fisheries Network (MAFFIN)
Masateru Onodera, KDDI Corp.
Tomohiro Otani, KDDI R&D Laboratories, Inc.
Hideki Otsuki, National Institute of Information and Communications Technology (NICT)
Shinji Ozawa, KDDI Corp.
Mark Prior, AARNet
Gang Qin, CSTNET, Chinese Network Information Center, Chinese Academy of Sciences
Nageswara Rao Oak Ridge National Laboratory
David Reese, CENIC / NLR
Donald Riley, Univ. of Maryland / SURA
Ken-ichi Sato, Nagoya University
Mamoru Sekido, National Institute of Information and Communications Technology (NICT)
Fay SHEU, NCHC
Takashi Shimizu, Nippon Telegraph and Telephone Corporation (NTT)
Kohei Shiomoto, Nippon Telegraph and Telephone Corporation (NTT)
Hisazumi Shirae, National Institute of Information and Communications Technology (NICT)
John Silvester, University of Southern California
Jerome Sobieski, Mid-Atlantic Crossroads
Hideaki Sone, Tohoku JGN2 Research Center, NICT / Tohoku University
David Su, NIST

Takahiro Sumitomo, National Institute of Information and Communications Technology (NICT)
Rick Summerhill, Internet2
Masatoshi Suzuki, KDDI R&D Laboratories
Kazuo Tachi, Japan Aerospace Exploration Agency (JAXA)
Atsushi Takada, Nippon Telegraph and Telephone Corporation (NTT)
Yoshihiro Takigawa, Nippon Telegraph and Telephone Corporation (NTT)
Jin Tanaka, KDDI Corp.
Christian Todorov, Internet2
Christopher Tracy, Mid-Atlantic Crossroads
Takahiro Ueno, National Institute of Information and Communications Technology (NICT)
Shigeo Urushidani, National Institute of Informatics (NII)
Nobuhiro Wakayama, Ministry of Internal Affairs and Communications (MIC)
Rod Wilson, Nortel Networks
Linda Winkler, Argonne National Lab, StarLight
Yufeng Xin, MCNC
Sugang Xu, National Institute of Information and Communications Technology (NICT)
Shigeki Yamada, National Institute of Informatics (NII)
Tsuyoshi Yamamoto, FUJITSU Laboratories

Appendix C: About LSN and the NITRD Program

Large Scale Networking (LSN) is one of the eight research areas – called program Component Areas (PCAs) – of the Federal government's Networking and Information Technology Research and Development (NITRD) Program. The $3-billion (President's FY 2007 Budget request) NITRD activity is a collaborative enterprise of 14 Federal agencies that represents the Government's main R&D investment portfolio in advanced computing, networking, software, and other information technologies. The NITRD member agencies are:

AHRQ – Agency for Healthcare Research and Quality
DARPA – Defense Advanced Research Projects Agency
DHS – Department of Homeland Security
DOE/NNSA – Department of Energy/National Nuclear Security Administration
DOE/SC – Department of Energy/Office of Science
EPA – Environmental Protection Agency
NARA – National Archives and Records Administration
NASA – National Aeronautics and Space Administration
NIH – National Institutes of Health
NIST – National Institute of Standards and Technology
NOAA – National Oceanic and Atmospheric Administration
NSF – National Science Foundation
NSA – National Security Agency
OSD and Service research organizations – Office of the Secretary of Defense and DoD Air Force, Army, and Navy research organizations

Representatives of the NITRD agencies that participate in LSN – NSF, OSD and DoD Service research organizations, NIH, DARPA, DOE/SC, NSA, NASA, AHRQ, NIST, DOE/NNSA, and NOAA – work together in the LSN Coordinating Group to coordinate Federal agency networking R&D in leading-edge networking technologies, services, and enhanced performance, including programs in new architectures, optical network testbeds, security, infrastructure, middleware, end-to-end performance measurement, and advanced network components; grid and collaboration networking tools and services; and engineering, management, and use of largescale networks for scientific and applications R&D. The Joint Engineering Team (JET) is one of three teams reporting to the LSN Coordinating Group:

The JET coordinates the network architecture, connectivity, exchange points, and cooperation among Federal agency networks and other high-performance research networks, and provides close coordination of connectivity, interoperability, and services among government, academia, and industry to improve end-to-end user performance and avoid duplication of resources and efforts. The JET also coordinates international connectivity and interoperability.

The Middleware And Grid Infrastructure Coordination (MAGIC) Team coordinates cooperation among Federal agencies, researchers, and commercial entities to research, develop, widely deploy, and use interoperable grid and middleware technologies, tools, and services and to provide a forum for international coordination.

The Networking Research Team (NRT) coordinates agency networking research programs and shares networking research information among Federal agencies. It provides outreach to end users by disseminating networking research information and coordinating activities among applications developers and end users. The other NITRD PCAs, each of which is also coordinated by an Interagency Working Group (IWG) or a Coordinating Group (CG) of agency representatives, are:

High-End Computing Infrastructure and Applications (HEC I&A)
High-End Computing Research and Development (HEC R&D)
Cyber Security and Information Assurance (CSIA)
Human-Computer Interaction and Information Management (HCI&IM)
High-Confidence Software and Systems (HCSS)
Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW) Software Design and Productivity (SDP)

In addition to the NITRD member agencies, a number of other Federal agencies also participate in the planning and coordination activities of NITRD's IWGs and CGs.
The NITRD Program is authorized by Congress under the High-Performance Computing (HPC) Act of 1991 (P.L. 102-194) and the Next Generation Internet Research Act of 1998 (P.L. 105-305). The strategic goals of the Program are to:

Provide research and development foundations for assuring continued U.S. technological leadership in advanced networking, computing systems, software, and associated information technologies

Provide research and development foundations for meeting the needs of the Federal government for advanced networking, computing systems, software, and associated information technologies

Accelerate development and deployment of these technologies in order to maintain world leadership in science and engineering; enhance national defense and national and homeland security; improve U.S. productivity and competitiveness and promote long-term economic growth; improve the health of the U.S. citizenry; protect the environment; improve education, training, and lifelong learning; and improve the quality of life

Overall NITRD Program coordination is carried out by the Subcommittee on Networking and Information Technology Research and Development, under the aegis of the Committee on Technology of the National Science and Technology Council (NSTC). The Cabinet-level NSTC is the principal means by which the President coordinates the diverse science and technology programs across the Federal government. The National Coordination Office for the NITRD Program (NCO/NITRD) provides technical, planning, and budgetary support for the NITRD Subcommittee and activities in the NITRD PCAs. The NCO/NITRD also supports the Networking and Information Technology Subcommittee of the President's Council of Advisors on Science and Technology (PCAST).

Appendix D: National Institute of Information and Communications Technology (NICT)

The National Institute of Information and Communications Technology (NICT) was established in April 2004 as a new incorporated administrative agency by the unification of Communications Research Laboratory (CRL), an incorporated administrative agency, and Telecommunications Advancement Organization (TAO), a chartered corporation.

NICT conducts research and development of information and communications technology that will support the forthcoming ubiquitous network society, from a coherent and integrated perspective encompassing many areas from its foundations to its applications, also offering comprehensive project support in the field of information and communications.

A new five-year middle-term plan period started in April 2006. At this important turning point, NICT has consolidated their past research and development into three areas of research, the "New-generation Network Construction Technology," the "Universal Communication Foundations Technology," and the "ICT for Safety and Security", while substantially reconstructing the research organization to promote such research and development.

Information and Communications Technology (ICT) is a field of technology that forms the foundations to support all the industrial activities. Crystallizing the future vision of the information and communications society described by the term "universal communication," NICT will continue sustaining national policies for information and communications from a technological perspective, with a goal of responsibly promoting the research and development of technologies that should support society's foundations. At the same time, NICT will endeavor to realize a vibrant society and prosperous lifestyles by closely cooperating with universities and the industrial world, including international research organizations, and by actively diffusing the outcome of research into society.

Appendix E Abbreviations/Acronyms

ATDnet – DARPA’s Advanced Technology Demonstration Network
AMPATH – AMericasPATH
Atlantic Wave (A-Wave) - East coast R&E optical networking infrastructure
BRUW – Internet2’s Bandwidth Reservation for User Work project
CA*net4 – The network infrastructure of CANARIE
CANARIE – Canada’s advanced Internet development organization
CENIC LA PoP – Corporation for Network
Initiatives in California’s Los Angeles Point of Presence
CERN – European Laboratory for Particle Physics
CISE – NSF's Computer and Information Science Engineering directorate
CHEETAH – NSF’s Circuit-switched
High-speed End-to-End Transport ArcHitecture project
CzechLight – CESnet – Prague - StarLight 10 G Network
DARPA – Defense Advanced Research Projects Agency
DoD – Department of Defense
DOE – Department of Energy
DOE/SC – Department of Energy Office of Science
DRAGON – NSF’s Dynamic Resource Allocation via GMPLS Optical Networks project
DREN – DoD's Defense Research and Engineering Network
DWDM - Dense Wave Division Multiplexing
EnLightened – NSF funded optical testbed
ESnet – DOE's Energy Sciences network
FIND – NSF’s Future Internet Network Design
GÉANT2 – Pan-European research and education network
Gbps – Gigabits per second
GENI – NSF’s Global Environment for Networking Investigations
GIG-EF – DoD’s Global Information Grid Evaluation Facilities
GigaPoP – Gigabit per second Point of Presence
GLIF – Global Lambda Integrated Facility
GLORIAD – Global Ring Network for Advanced Application Development, funded as an international partnership among the US, Russia, China, Netherlands, Canada, Korea and the Scandiavian countries.
GMPLS – Generalized Multi-Protocol Label Switching
GOLE – Global Open Lambda Exchange
HOPI – Internet2’s Hybrid Optical Packet Internet project
I/O – Input/output
IETF – Internet Engineering Task Force
iGRID – Annual international grid workshop
InfiniBand – A point-to-point high-speed switch fabric interconnect architecture
IP – Internet Protocol
ITU – International Telecommunications Union
JET – LSN Coordinating Group's Joint Engineering Team
JGN2 – Nation-wide advanced networking research testbed in Japan

KREONet2 – Korea-US advanced network
KRLight – Global Open Lambda Exchange in Seoul, South Korea
LHC – Large Hadron Collider
LSN – Large Scale Networking
LUSTRE – An open source distributed file system
MAN LAN – Manhattan Landing exchange point
MAX – Mid-Atlantic Exchange
Mbps – Megabits per second
MPLS – Multi-Protocol Label Switching
NASA – National Aeronautics and Space Administration
NCO/NITRD – National Coordination Office for the NITRD Program
NetherLight – Amsterdam – StarLight experimental 10 G testbed
NGIX – Next Generation Internet Exchange
NGN – Next-Generation Network
NICT – National Institute of Information Communication Technology
NITRD – The Federal Networking and Information Technology Research and Development Program
NLR – National LambdaRail
NOC – Network operations center
NREN – NASA's Research and Education Network
NRENs – National research and education networks
NSA – National Security Agency
NSF – National Science Foundation
O&M – Operations and management
OC-192 – Optical Carrier rate of nearly 10
gigabits per second
OEP – Open Exchange Point
OIF – Optical Internetworking Forum
OMB – Office of Management and Budget
ONT – Optical network testbed
OPN – Optical private network
OSCARS – DOE/SC’s On-demand Secure Circuits and Advanced Reservation System project
PCAST – President’s Council of Advisors on Science and Technology
PITAC – President's Information Technology Advisory Committee
PoP – Point of Presence
PNWGP - Pacific Northwest GigaPoP - Seattle.
Pacific Wave (P-Wave) – West coast R&E optical networking infrastructure
OGF – Open Grid Forum
QoS – Quality of service
OptIPuter – NSF funded distributed infrastructure based on dynamic optical networking
OMNInet – Metro optical networking research testbed
R&D – Research and development
R&E – Research and education
RON – Regional optical network
SINET – An advanced Science Information Network in Japan with international connections
SOA – Service-oriented architecture

SOX – South Atlantic Optical Exchange
StarLight – NSF-funded international optical exchange point
StarPlane – Advanced optical network in the Netherlands
SURFnet – Netherlands' research and education network
Tbps – Terabits per second
T-Lex – Tokyo Lambda Exchange
TCP/IP – Transmission Control Protocol/Internet Protocol
TeraGrid – NSF's grid computing initiative
TransLight – NSF funded international advanced R&E network
UCLP – User-controlled light path
UKLight **–** United Kingdom optical optical research network
USN – DOE/SC's UltraScience Network
VIOLA – Optical research testbed in Germany
VLAN – Virtual local area network
WAN – Wide area network
WHREN Western Hemisphere Research and Education Network, NSF funded R&E network connecting AMPATH to South America
WIDE – A national advanced experimental network in Japan.

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